ACOUSTO-OPTIC CHANNELIZER STUDY

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Abstract

A coherent acousto–optic spectrum analyzer has been used to channelize a wideband rf signal into several narrowband signals. The channelizer features a Bragg cell used to physically spread out the wave's spectrum, a reference beam, and a fiber optic array with each fiber leading to an optical detector. A perfect channelizer would allow coherent recombination of the detected signals to reconstruct the original rf input. We have measured and studied the effects due to imperfections in the channelizing process caused by the physical setup. These imperfection effects can be characterized as notches in bandpass frequency filter. Experimentally these notches have depths of 0.5 to 1.5 dB. The phase linearity of the response is within 5 degrees. The effects of these notches and experimental techniques to alleviate the effects on the signal will be described. Experimental results demonstrating the successful transmission and recovery of a BPSK spread–spectrum signal are also presented.

1 Introduction

Wideband rf signals are becoming more frequent and current techniques for locating a signal of interest are limited in their ability to cover the entire spectrum [1]. The use of an acousto–optic receiver might be one technique to solve some of the problems in locating and analyzing modern wideband signals. We have studied a receiver designed to receive and channelize wideband signals to be recorded on a conventional multi–track tape recorder with channel bandwidths of 750 kHz. The system is illustrated in Fig. 1

In this system the wideband rf signal is fed into a Bragg cell after the appropriate frequency shifting to place the rf signal with the bandpass of the Bragg cell transducer. The Fourier spectrum of the rf signal is available spatially in the focal plane of the transform lens. A reference wave from the laser source that has bypassed the Bragg cell in is combined with the spectrum at the focal plane of the lens [2]. Figure 2 shows a detailed view of the optical pickup and detection system. An linear array of fiber optic cables is placed in the detector plane. Each fiber has a 0.98 mm core diameter and an external diameter of 1.0 mm.

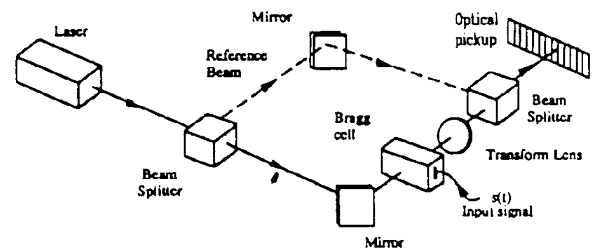

Figure 1: Schematic of acousto–optic channelizer.

The focal length of the lens is chosen so that each fiber intercepts a 750 kHz of the spectral width of the signal. Each fiber passes the signal component plus a piece of the reference beam to its own receiver, consisting of a pin photodiode and a bandpass amplifier. Since the reference beam is present, the detection is coherent and both the amplitude and phase of the rf component is preserved in the output voltage from the receiver [2]. In principle, the output of each receiver would be recorded on a track of the multi–track tape recorder. The coherent summation of the output of all tracks upon playback would reconstruct

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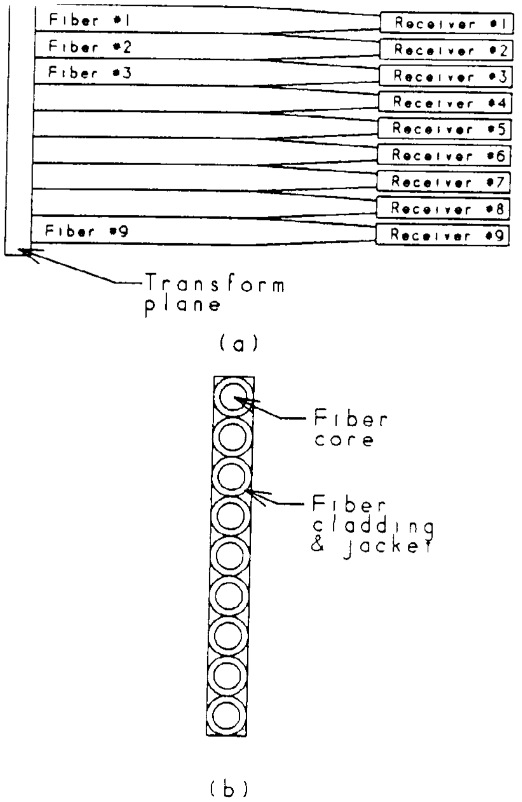

Figure 2: Optical pickup and detection system, (a) side view and (b) end view.

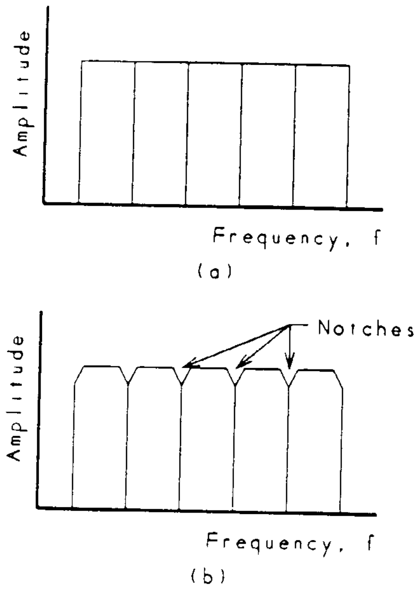

Figure 3: Spectral response for (a) an idealized channelizer and for a non-ideal channelizer.

the wideband signal for further analysis; in our laboratory simulation, we do not record the components but coherently sum the outputs of the receivers directly to immediately reconstruct the signal.

The idealized frequency response of the system is shown in Figure 3a. Each component of the spectrum is adjacent to its neighbors with no amplitude (or phase) variation across the boundary. In the actual system, however, the cladding region and jacket of the fibers (shown in Fig. 2b) will not be able to guide the light to the receivers. Part of the components will be missing, as shown in Figure 3b. Here we find "notches" in the frequency response due to the regions of the optical fiber that will block transmission of the optical fiber. Figure 4 shows the measured frequency response of a three-channel system with a uniform-amplitude swept-frequency signal. The presence of the notches (of about 5 dB depth) between the channels is evident. (The notch depth has been exaggerated in this figure by misalignment of the

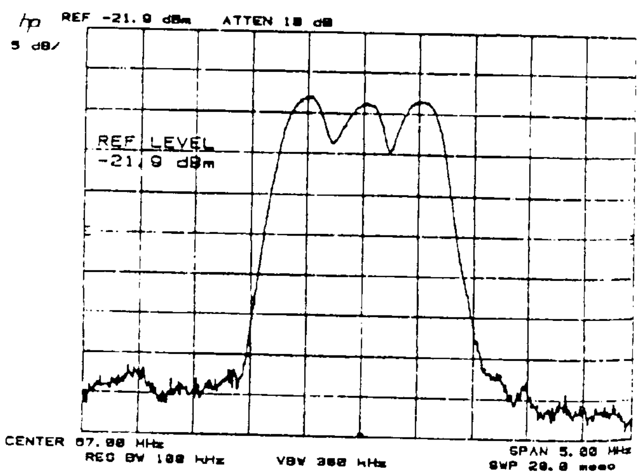

Figure 4: Measured (misaligned) channelizer response demonstrating channel notches.

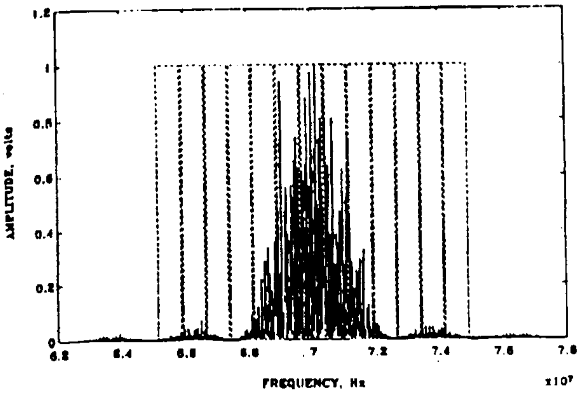

Figure 5: Computed spectrum of BPSK test signal with filter response (dotted curve) superimposed.

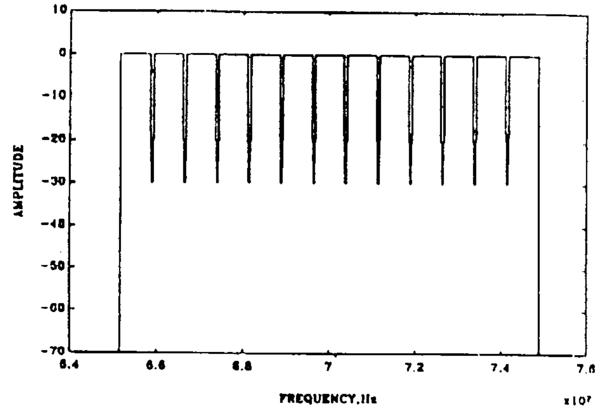

Figure 6: Representative notch filter used in model.

components; with careful alignment the notch depths are typically 1 dB [3].)

The purpose of this study was

1. to model the notches theoretically and predict their effect on the recovery of various wideband signals passed through them, and
2. to experimentally pass a wideband signal through the system and recover the information for corroboration of the model.

2 System model

The modeling study [4, 5] used Matlab to simulate the high-frequency wideband signal. (The signal studied was a pseudorandom binary-phase-shift-keyed (BPSK) signal at 70 MHz.) The sampled signal was transformed (see Fig. 5, passed through a notch filter with variable parameters (see Fig. 6 for an example). The filtered signal was inverse-transformed, the data recovered with a simulated coherent detector, and errors found by comparison of the recovered data sequence with the input sequence.

The data sequence was accurately recovered when no notches were present, as expected. When the notches were present, the results indicated minimal errors in the recovered data for notch depths of 1 to 2 dB. Notch depths of 5 to 6 dB caused considerable degradation. The signal recovery was also found to be sensitive to the location of the notches relative to the carrier frequency. A wide and/or deep notch located such the carrier frequency was within the notch caused much more loss of data than when the notch was located well away from the carrier.

3 Experimental measurements

Experimentally the channelizer system has been set up in our laboratory utilizing a Bragg cell centered at 75 MHz. Three channels of the receiver system were implemented for a total signal bandwidth capability of 2.25 MHz. A BPSK signal generator was designed, built, and tested[6] that could generate a pseudorandom data stream that modulated a subcarrier at 1 MHz which, in turn, was frequency shifted up to 67 MHz to be within the Bragg cell passband. A coherent demodulator was also built [6] to recover the carrier frequency and coherently detect the data stream by phase comparison of the signal with the recovered clock.

Figure 7 shows the experimentally observed spectrum of the BPSK input signal. Superimposed on the figure (dotted lines) is the passband of the three-channel channelizer that was used. The amount of spread in the BPSK spectrum is user-controllable by altering the data rate with higher data rates causing wider spectra. Figure 8 shows the measured output spectrum of the signal after being passed through the three-channel channelizer, detected, and summed to reconstruct the approximation of the original signal. The system was aligned to minimize the notches in the frequency response of the system to just smaller than 1 dB. The effect of the notches is not discernible in the spectra shown and proved to be negligible in

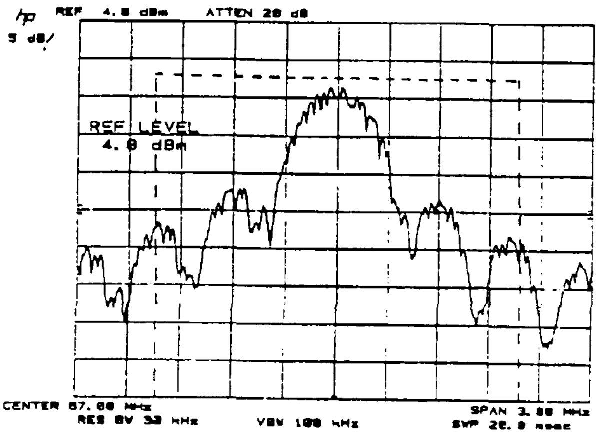

Figure 7: Spectrum of the generated BPSK signal. Dotted rectangle shows the extent of passband of the three–channel acousto–optic channelizer.

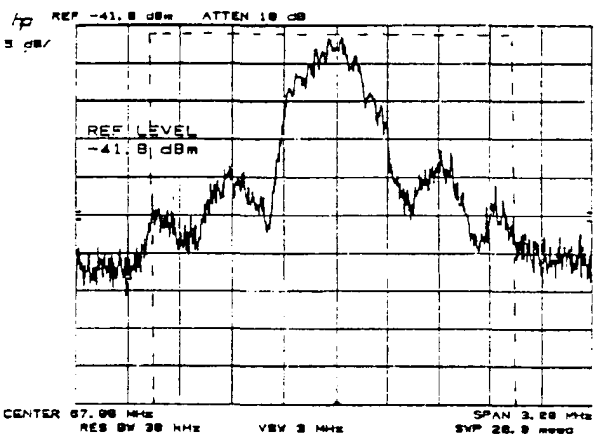

Figure 8: Measured spectrum of the output BPSK signal after passing through the three–channel channelizer and being reconstructed. Dotted rectangle shows the extent of passband of the channelizer.

recovering the data stream. Experimentation showed that the center lobe and six sidelobes (i.e., three sidelobes on each side of the center frequency) were required to accurately recover the data rate. Inclusion of more than these six sidelobes did not increase an already perfect data recovery; exclusion of the outer third sidelobe cause signal recovery to fail. It was also observed that the input rf signal had to be sufficiently amplified to provide power in the outer sidelobes. Lack of power would cause a loss of data recovery even though the channelizer offered sufficient bandwidth.

4 Summary

We have successfully demonstrated the operation of a three–channel acousto–optic channelizer. Modeling studies predict negligible effects from the notches induced by the fiber–optic optical pickup as long as the notches are 1 dB or less in depth and the notches do not occur at a critical frequency location such as the carrier frequency. Further modeling is required to exercise the various variables (including notch width, depth, location and shape) and for various modulation formats.

References

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